Editorials

Five Years in the Area of Input-Output and Hybrid LCA

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Looking Back

As far as the online Subject Index search can tell, the first article published in *Int J LCA* involving the subject area of input-output and hybrid LCA was in 2002 (Suh & Huppes 2002). Recognizing the potential of the subject area, the journal quickly established a new section on the subject area a year later, releasing a call for submission in 2003 (Suh 2003). Until now, slightly over a dozen peer-reviewed articles on the subject have been published in *Int J LCA*.

Although the number may not sound like a lot, each and every piece of the contributions really advanced our knowledge and understanding in various fronts of the subject. The topics brought to the readership of *Int J LCA* by these contributions include applications of a Waste Input-Output (WIO) model for electric appliances (Kondo & Nakamura 2004), comparison of IO and process LCA databases (Mongelli et al. 2004), risk-based human health impacts (Nishioka et al. 2005a, Nishioka et al. 2005b), dynamics and socio-economic impacts (Hondo et al. 2006), a case study on transportation (Facanha & Horvath 2006), hybrid Life Cycle Cost (LCC) (Nakamura & Kondo 2006), regional IO-LCA (Yi et al. 2007, Cicas et al. 2007), and efficient computational algorithms and analytical tools (Peters 2007, Suh and Heijungs 2007). These contributions cover both the development of a theory as well as practical applications of using Input-Output Analysis (IOA) for Life Cycle Assessment (LCA).

In the course of the development in an Input-Output and hybrid LCA section over the last five years, the Input-Output approach has grown from a tool still foreign to general *Int J LCA* readership into an important part of LCA research and practice. Input-Output approach is no longer just a tool to assist Life Cycle Inventory (LCI) phase, and it has embraced various areas of LCA modelling and applications including dynamic modelling, product environmental policy, waste management and LCC. Evolution of an input-output and hybrid approach in connection to LCA was also clearly visible at the two recent conferences: the International Society for Industrial Ecology (ISIE) 2007 meeting in Toronto, Canada and the 16th International Input-Output Conference in Istanbul, Turkey.

Waste Input-Output Model

Among other things, what emerged as a host of variety of methodological developments and applications in LCA was the Waste Input-Output (WIO) model (Nakamura & Kondo 2002). Structurally, the WIO model can be described as an integrated hybrid model, where both physical and monetary flows are represented in a single technology matrix covering both foreground processes and background economy (Suh et al. 2004). In the case of the WIO model, foreground processes are waste management processes described in physical units and constructed using engineering data. The waste treatment sector is connected to the national economy through supplying and consuming wastes and products (cf. Suh 2004).

The basic framework of WIO model has then connected to the questions of decision analytic framework (Kondo & Nakamura 2005), LCC (Nakamura & Kondo 2006) and materials flow and composition (Nakamura & Nakajima 2005, Nakamura et al. 2007). Furthermore, WIO model has been quickly absorbed by other fields of industrial ecology research opening new possibilities of mutation between IOA, LCA and industrial ecology studies.

A New Associate Subject Editor

Recognizing the growing applications of the WIO model and the contribution by Professor Shinichiro Nakamura, the editorial leadership of *Int J LCA* invited Dr. Nakamura as a new Associate Subject Editor for the Input-Output and hybrid LCA subject of the journal. Together with the Subject Editor, Sangwon Suh, Dr. Nakamura will provide his insights and experiences as an Associate Subject Editor for the submissions made to the Input-Output and hybrid LCA subject area.

What follows is an observation by the authors of this Editorial on how recent developments – including the WIO model – address various challenges around IO-LCA.

Challenges to IOA as a Tool for LCA

It is generally understood that IO-LCA and process-LCA both have strengths and weaknesses (Suh & Huppes 2005). As compared to process-LCA, main weaknesses of IO-LCA are argued to be (1) the low level of detail (or coarse sector resolution), (2) data age, (3) use of a monetary unit, and (4) neglecting (or not explicitly considering) the use and EoL phases. The first three points are often made among the LCA community. While the fourth point is often raised in the IO community, the same does not seem to apply to the LCA community. In the following, we try to address each of these points under consideration of the latest developments which have been recorded.

Official Input-Output Tables (IOTs) cover the entire economy using detailed government statistics that are often inaccessible to the general public. Due to the wide coverage of the table and the use of enormous amount of data that are often sensitive, IOTs have to be aggregated, and it often takes a few years to process the data before a table is officially published. Therefore, relying only on IO data for detailed LCA is not desirable, which is certainly a limitation of IO-LCA.

Using the hybrid approach, however, these problems can be resolved efficiently: sector-resolution is selectively gained to the level necessary for the foreground system using detailed, process-specific information, while the background system still covers the entire national economy represented by an IOT (see Moriguchi et al. 1993 for an early example of hybrid approach). The possibility of combining the two systems with different resolution in a consistent framework offers a great advantage for both the IO and LCA sides (see, e.g., Nakamura & Nakajima 2007).

The use of monetary value in IOA implies that the analytical results obtained may be vulnerable to price fluctuations and inhomogeneity. Flow of a product in monetary terms, however, can always be converted into a physical term, given that additional information is available. Again, the use of hybrid techniques effectively solve the problem by selectively replacing key product flows in monetary terms into physical terms. It is notable that the original formulation of input-output structure by Wassily Leontief was in mixed units, where a number of units – including both physical and monetary ones – are used at the same time. Another example might be the pollution abatement model by Wassily Leontief, where mixed unit framework reappeared (Leontief 1971). Again, this is also primarily a data issue and the problem has been successfully addressed through a hybrid approach.

An LCA is concerned with environmental impacts of a product through its whole life cycle, which consists of production, use, and EoL. In its original form, however, IOA is only concerned with the production phase. Although monetary IO tables usually have a waste management sector, the way how it is treated is not sufficient for LCA purposes. The WIO model elegantly solves the problem by developing an extended accounting scheme with the flow of waste and waste management processes, the WIO table, and the associated analytical model, the WIO model (Nakamura & Kondo 2002). The WIO has closed the loop of life cycle within the framework of IOA. See also Hondo et al. (1996) and Joshi (1999), where process-specific information is selectively added to cover the areas where information in an IOT is not sufficient.

We tried to show that the four weaknesses that are often referred to as obstacles of IOA for the use in LCA have been successfully addressed in the course of the developments in the field of IO and hybrid LCA. Certainly, however, we have no intention to imply that all problems are solved in IO and hybrid LCAs. There are unresolved issues that are more persistent, and for which continued efforts should be made. For instance, as international trade has grown to be an integral part of the global economy, applicability of a national input-output table and analyses thereof is becoming increasingly limited for addressing global challenges; lack of compatibility between IOTs of different countries also makes it difficult to compare IO-LCA results of different countries; quantitative uncertainty analysis has rarely been attached to IO-LCAs, as basic uncertainty information for individual elements of an IOT is generally unavailable. These are only a few examples to which future scientific efforts will need to be directed, and the section on IO and hybrid LCA of *Int J LCA* will remain as an open forum where such efforts are communicated.

Concluding Remarks

As the only international journal entirely devoted to the development of LCA, *Int J LCA* has been an important medium for all areas of scientific communication among LCA researchers and practitioners. The role of the journal in field of Input-Output and hybrid LCA haven't been an exception. Cutting-edge research has been promptly reported to the readership of the journal, and the contributions made advancements in various fronts of IO and hybrid LCA research. With the new Associate Subject Editor, we hope that the contributions of *Int J LCA* to the field will be even more frequent. We will be looking for quality submissions in this area including a theory and applications of the WIO model.

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